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Forecasting of the Effect of Potential Aero Engine Modifications on Life Cycle Cost

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1) Introduction

The life-time of an engine normally extends to over 50 years. During this long period engine technology moves on. New materials, new calculation procedures and new design features become available.

Introducing new technological elements is relatively easy during the early engine design phase.

The more mature the engine design becomes, the more difficult it is to introduce new features, because they affect numerous other components or design parameters.

It is not possible to incorporate a great number of new features into an engine which is already being operated by customers for financial reasons as well as from a logistical point of view.

During the operation phase the benefit of introducing modifications must be thoroughly weighed with respect to quite a number of parameters.

However, some modifications are important to be implemented due to flight safety reasons or due to cost saving aspects. The latter aspect will be discussed in this paper.

2) Basics of the Life Cycle Cost analysis

To find out, if a modification saves money during the rest of the operational life of the engine a business case has to be established.

Due to the existing interdependencies of the relevant parameters, cost estimation is a complex task.

For proper calculation of the business case, information such as

- number of aircraft
- existing engine standards
- maintenance, repair and overhaul procedures
- spare parts supply

- documentation
- etc.

must be available and considered very carefully. This is done by means of the so-called Life Cycle Cost Studies (LCC Studies).

The Life Cycle Cost calculation covers all phases of an engine life, starting from the beginning of its development until its retirement from the service, i.e. the cost of the

- development phase,
- procurement phase
- and operation phase.

Of major importance for an LCC analysis is the operation phase.

Furthermore, it is important to consider how introduction of a modification into the fleet is to be performed. The two extreme positions are on the one hand to introduce a modification during natural arisings. In this case introduction of the modification will take a long time. On the other hand a quick retrofit campaign could be run. And, of course, in between there are many different ways with different implications concerning cost and introduction time of a modification.

Three different phases have to be taken into account for changing an engine standard:

- operation with the current standard,
- conversion phase,
- operation with the new standard.

These phases are overlapping and dependent on the embodiment procedure chosen.

Each phase has its specific cost parameters and of course these parameters depend on each other.

3) Life Cycle Cost analysis

To calculate life cycle costs with respect to the above mentioned influencing parameters, a computer-based programme was developed at MTU which is capable of incorporating maintenance, repair and operation parameters.

The computer code has no restrictions as to the number of aircraft.

The required input parameters are as follows :

- Engine delivery rate - squadron/fleet
- Flight hours/years of operation
- Component life characteristics
 - Failure mode distribution function
 - Probability of secondary damage
 - Life limitations - remaining issue service lives

- Maintenance strategies (concepts)
- Various maintenance concepts
- Inspection intervals (borescope inspection)
- Preventive maintenance
 - Maintenance levels
 - Maintenance turnaround times, transportation
 - Maintenance capacities
 - Man hours per event
- Engine, module and component prices

- The possible output parameters are :
- Engine, module, component and accessory arisings
- Failure rates depicted by removal reason
 - scheduled/unscheduled
 - secondary damage
 - random or time-dependent failure
- Repairs shown by maintenance level and reasons for removal
- Maintenance/repair man hours
 - by maintenance level
 - by scheduled/unscheduled maintenance action
- Material costs of major components (quantity and DM/EFH)
- Spares requirements (engines/modules(components))

4) Results

The results are shown in a typical graph of a LCC Study.

5) Summary

The evaluation of the cost effectiveness of an engine modification is affected by a lot of parameters which depend on each other in many different ways. Due to the great amount of variables to be considered, a computer-based simulation model is necessary for the calculation.

One computer model was described in this paper. A number of possible results were discussed based on typical examples. Depending on the input parameters and the philosophy chosen, the results are varying.

This clearly indicates that the computer programme, although being a very powerful tool, does not show correct results, if there is no understanding of the calculation philosophy and if there is not a correct set of input parameters available.

However, if operated by specialists, the programme is a very helpful tool for both the engine manufacturer and the operator. The benefit of a modification will show up very clearly.

Overview of the mainpoints for the presentation

- The life-time of an aero engine extends to over 50 years.
- Example : Fuel consumption has been significantly reduced over the years.
- Modifications are necessary due to flight safety and cost reasons.
- Life cycle cost (LCC) analyses of modifications result in invaluable contributions to the Business Case.
- Life-cycle cost cover all phases of an engine life.
- Of major importance for an LCC analysis is the operation phase.
- Each modification is carried out in three phases.
- Each phase has its specific relevant cost parameters.
- The various cost parameters are inter-dependent.
- MTU has developed a computer-based LCC simulation model for maintenance, repair and operation.
- The required input parameters vary for technical and service-related modifications.
- The output parameters can be selected individually and the output used for further processing.
- The results are graphs and diagrams for easy comparison of various options.

Paper 2: Discussion

Question from R Bolwell – UK MoD

How much does safety cost?

Presenter's Reply

It depends on the special case, of course. Safety must be ensured at any time during the operational phase of an engine life cycle. If a flight safety case occurs, immediate actions are necessary to solve the problem. Different solutions are possible, one way may be to introduce a modification.

In the case of a flight safety issue, it is not necessary to base the decision on a detailed business case and to perform intensive Life Cycle Cost (LCC) studies because, to avoid the fleet being grounded, action must be taken in all circumstances.

On the other hand, a non-flight safety related modification could be offered to the customer. In which case, the customer should be provided with an understanding of the benefits to enable him to decide whether or not to procure the modification.

This second case is the main field for LCC calculations.

Question from D K Hennecke - Germany

How sensitive is your prediction to the accuracy of the input data? Which parameters are the most critical?

Presenter's Reply

As presented in the paper, all cost parameters are strongly interdependent. The main challenge is in setting up a correct set of input data; the results depend strongly on this input data.

The following factors would exert major influence over the LCC results:

- The way in which the modification was introduced, ie through a campaign or on natural attrition arisings.
- The residual value of the old parts, ie whether they could be reused or not.
- The cost of the affected components.
- The subsequent reduction in maintenance activity.

Due to the large number of parameters exerting influence over the LCC forecast, it is not possible to identify critical drivers; the relative importance depends upon the case in question.